MICRO WAVE CELLULAR ARCHITECTURE

Technical Field

5   The present invention relates to Local Multipoint Communication Systems (LMCS), which are also known as Local Multipoint Distribution Systems (LMDS).

Background Art

LMCS/LMDS networks comprise a plurality of suitably arranged and configured transmitters operating on a frequency assignment basis. Such networks
10   typically operate using QAM, QPSK, or some other digital modulation scheme. The networks are designed to minimise problems of intersymbol interference (ISI) at receiving sites where two or more signals could potentially be received.

There are a number of frequency assignment techniques known to the industry including:

15   (1)   frequency division, in which an allocated spectrum is divided to form sets of frequencies which are applied to a cell structure in such a fashion that adjacent nearby cells operate on sufficiently different frequencies to avoid ISI;

(2)   signal polarisation, which can effectively create or extend the number of available frequencies; and
20   (3)   half channel interleaving, which can be used with some modulation schemes to allow a particular frequency to be reused in nearly adjacent cells.

It has been proposed to carry multiple video channels on such systems. In some countries, one or more bands around 26, 27 or 28 GHz have been reserved, whilst in others, the reserved bands are around 38 to 40 GHz. At these frequencies, the
25   propagation of radio waves is relatively directional.

Disclosure of the Invention

In a first aspect, the invention provides a transmission network for communicating information at directional radio frequencies, said network comprising:
30   a broadband network servicing a first area, and including a plurality of first and second transmitters, the direction of transmission of each first and second transmitter lying substantially parallel to a first geographical axis, and

a broadcast network servicing a second area substantially overlaying the first area, and including a plurality of third and fourth transmitters, the direction of
35   transmission of each third and fourth transmitter lying substantially parallel to a second geographical axis, the second axis being orthogonal to the first axis,

wherein the broadband network transmits in a first frequency band, and the broadcast network transmits in a second frequency band, the first frequency band being substantially the same as the second frequency band.

In a second aspect, the invention provides a transmission network for communicating information at directional radio frequencies, said network comprising:

(a)   a plurality of first, second, third and fourth cells, each first, second, third and fourth cell comprising:

a first transmitter for transmitting radio frequency information in a first direction to define a first reception footprint substantially within the cell, the first transmitter being disposed at or adjacent a periphery of the cell, and

a second transmitter for transmitting radio frequency information in a second direction substantially opposed to the first direction to define a second reception footprint substantially overlapping the first reception footprint, the second transmitter being disposed at or adjacent the periphery of the cell at a position substantially opposed to the first transmitter,

the first, second, third and fourth cells being generally circular or oval in plan, of similar size and transmitting at first, second, third and fourth frequencies respectively, the first transmitter of each first cell being disposed at or adjacent the second transmitter of an adjacent second cell, and the first transmitter of each third cell being disposed adjacent the second transmitter of an adjacent fourth cell,

the plurality of cells being arranged such that the first and second directions, in which the first and second transmitters respectively transmit, are parallel;

(b)   a first rectangular array of the first and second cells, the periphery of each first and second cell abutting the peripheries of respective surrounding first and second cells, wherein rows of the first rectangular array in a direction parallel to the first and second directions comprise alternating first and second cells, and each of the rows of the first rectangular array orthogonal to the first and second directions includes either first or second cells, and

(c)   a second rectangular array of the third and fourth cells, the periphery of each third and fourth cell abutting the peripheries of respective surrounding third and fourth cells, wherein rows of the second rectangular array in a direction parallel to the first and second directions comprise alternating third and fourth cells, and each of the rows of the second rectangular array orthogonal to the first and second directions includes either third or fourth cells,

wherein the cells of the second rectangular array are displaced with respect to the cells of the first rectangular array by approximately the radius of a cell in the first direction, and by approximately the radius of a cell in a direction orthogonal to the first direction.

5   In the present specification, references to "frequencies" and "different frequencies" are intended to include signals having different frequencies but the same polarisation, and signals having the same frequency but different relative polarisations. These references are also intended to cover bands of frequencies, as well as single frequencies.

10   Further, references to a transmission or broadcast "direction" or the like are intended to refer to a general orientation of the transmitter involved. As will be apparent to those skilled in the art, transmission in a given direction is intended to include transmission of a footprint in that direction onto the ground.

15   **Brief Description of Drawings**

Various preferred forms of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1(a) is a schematic view of a cell according to a first aspect of the invention;

Figure 1(b) is a schematic view of a cell for use with a network according to a second aspect of the invention;

Figure 2 is a schematic view of a plurality of cells forming a broadband network according to the second aspect of the invention.

Figure 3 is a schematic view of the network shown in Figure 2, illustrating transmitter positions and frequency allocation for each cell;

Figure 4 is a schematic view of the network of figure 3 with an overlapping orthogonal broadcast network;

Figure 5 is a simplified graph showing exemplary spectrum allocations for the network shown in figure 4;

Figure 6(a) is a schematic view showing interconnection of a plurality of cells to form a cluster;

Figure 6(b) is a schematic view showing tessellation of multiple clusters such as those shown in 6(a) to form a network of clusters;

Figure 7 is a schematic view showing a broadcast network overlaying the broadband network of Figure 3, the broadcast network using FM modulation;

Figure 8 is a schematic view of broadband network such as that shown in Figure 2, in which frequency assignment of the spectrum shown in Figure 5 is made;

Figures 9 and 10 are schematic views showing interference of the broadband outbound and broadcast network respectively;

Figure 11(a) is a schematic view of the network shown in Figure 3, showing distribution and polarisation of spectrum allocation 'B' as shown in Figure 5;

Figure 11(b) is a detailed view of portions of networks shown in Figure 11(a), illustrating the return path for broadband services;

Figure 12(a) is a schematic view of a plurality of cells arranged to form a first rectangular array; and

Figure 12(b) is a schematic view of a plurality of cells arranged to form a second rectangular array configured for use with the first rectangular array shown in Figure 12(a).

Detailed Description of Preferred Embodiments

Referring to the drawings, and Figure 1(a) in particular, there is provided a cell 1 for use in a transmission network for communicating information at directional radio frequencies. The cell 1 includes a first transmitter 2 for transmitting radio frequency information in a first direction 4 to define a first reception footprint 6 which substantially covers cell 1. The first transmitter 2 is disposed at a periphery 8 of the cell 1. The cell 1 also includes a second transmitter 10 for transmitting radio frequency information in a

second direction 12 substantially opposed to the first direction 4, to define a second reception footprint 13 which also effectively covers the cell 1. The second transmitter 10 is also disposed at the periphery 8 of the cell 1, at a position substantially opposed to the first transmitter 2. In the preferred embodiment the reception footprint 13 defined by the second transmitter 10 substantially overlaps the reception footprint 6 defined by the first transmitter 2.

The cell 1 is generally circular in plan, and represents a coverage yielded by a 64 degree horn having a 28 dB front to back ratio and 17 dB sidelobe at 90 degrees. Whilst other cell shapes may be utilised, the circular cell shown is preferred due to the way in which a plurality of such cells may be arranged in a substantially regular array or matrix to form an improved transmission network. It will also be appreciated that the horn parameters given are exemplary only, and that others values could be substituted depending upon the particular implementation of the invention. Turning to Figures 2 to 11(b), there is provided a transmission network 14 including a plurality of the cells 1, the cells 1 being arranged such that the first direction 4 and the second direction 12 are parallel.

In a preferred form of the invention shown in Figure 3, the transmission network 14 includes a plurality of first, second, third and fourth cells 16, 18, 20 and 22. Each of the first, second, third and fourth cells 16, 18, 20 and 22 are generally circular in plan, are of similar size, and transmit at first, second, third and fourth frequencies respectively.

The first transmitter of each first cell 16 is disposed at or adjacent the second transmitter of an adjacent second cell 18 and a first transmitter of each third cell 20 is adjacent the second transmitter of an adjacent fourth cell 22. In this way there is defined a parallel "back to back" edge transmission network.

As best shown in the embodiment of the invention in Figures 12(a) and (b), the transmission network includes a first rectangular array 17 of the first and second cells 16 and 18, a periphery of each first and second cell abutting the peripheries of respective surrounding first and second cells. Rows 19 of the first rectangular array 17 in a direction parallel to the first and second directions comprise alternating first and second cells, whilst each of the rows 21 of the first rectangular array 16 orthogonal to the first and second directions consists of either first or second cells.

The transmission network also includes a second rectangular array 23 of the third and fourth cells 20 and 22, the periphery of each third and fourth cell abutting the peripheries of respective surrounding third and fourth cells. Rows 24 of the second rectangular array 23 in a direction parallel to the first and second directions comprise alternating third and fourth cells, and each of the rows 26 of the second rectangular array orthogonal to the first and second directions consist of either third or fourth cells. The cells of the second rectangular array 23 are displaced with respect to the cells of the first

rectangular array 16 by approximately the radius of a cell in the first direction, and by approximately the radius of a cell in a direction orthogonal to the first direction.

In a preferred form, the first, second, third and fourth frequencies used by the first, second third and fourth cells respectively are generated from a pair of frequencies or frequency bands. By applying horizontal and vertical polarisation to each of the two frequencies, effectively a full frequency set is generated. This method is only useful at frequencies sufficiently high that polarisation remains generally stable throughout a transmission area. Relatively low frequency transmissions do not allow for stable polarisation.

In a preferred embodiment, the transmission network forms part of a broadband two way network, in which return signals are transmitted from one or more return sites within each cell. To avoid interference, the return signals are transmitted at one or more frequencies other than the first, second, third or fourth frequencies. Depending upon the position of a return site within a cell, it may transmit its return signal towards either the first or second transmitter. A suitable receiver is located adjacent each transmitter to receive returned signals, thereby enabling a true broadband service.

Referring to Figures 4 and 7 to 10, in a preferred form, the transmission network 14 (shown in dotted lines) further includes an overlaid broadcasting network (solid lines) for one-way broadcast of information. Typically, this information will be multiple video channels or the like, but can also include radio or any other transmitted media. As best shown in Figure 4, the broadcasting network includes a plurality of fifth cells 30 and sixth cells 32.

Each fifth cell 30 includes a fifth transmitter 34 for transmitting radio frequency information in a third direction 36 orthogonal to the first and second directions onto a reception footprint 35 substantially within the fifth cell. Each fifth transmitter 34 is disposed at a periphery of the corresponding fifth cell 30. Figure 1(b) shows the general arrangement of the fifth and sixth cells 30 and 32.

Each sixth cell 32 includes a sixth transmitter 38 for transmitting radio frequency information in a fourth direction 40 substantially opposite the third direction 36 to define a reception footprint 42 substantially within the sixth cell 32. Each sixth transmitter 38 is disposed at the periphery of the corresponding sixth cell 32.

In the broadcasting network, the fifth transmitter 34 of each fifth cell 30 is disposed adjacent the sixth transmitter 38 of an adjacent sixth cell 32. Furthermore, there is provided a third rectangular array of the fifth and sixth cells 30 and 32 , similar to the arrays shown in the Figures 12 (a) and 12 (b). The peripheries of each fifth cell 30 and sixth cell 32 abut the peripheries of respective surrounding fifth and sixth cells. Rows of the third rectangular array in a direction parallel to the third and fourth directions and comprise alternating fifth and sixth cells 30 and 32. Conversely, each

row of the third rectangular array parallel to the first and second directions consists of only fifth cells 30 or sixth cells 32.

There is also provided a fourth rectangular array of the fifth and sixth cells 30 and 32, once again, in a similar fashion to that shown in Figures 12 (a) and 12 (b). The periphery of each fifth and sixth cell 30 and 32 abuts the peripheries of respective surrounding fifth and sixth cells. Rows of the fourth rectangular array in a direction parallel to the third and fourth directions comprise alternating fifth and sixth cells 30 and 32. Conversely, each row of the fourth rectangular array parallel to the first and second directions includes only fifth cells 30 or sixth cells 32.

The cells of the fourth rectangular array are displaced with respect to the cells of the third rectangular array by approximately the radius of a cell in the third direction and by approximately the radius of a cell in the first direction.

When the broadcasting network is deployed in conjunction with the transmission network, the cells of the third rectangular array are displaced with respect to the cells of the first rectangular array by approximately the radius of a cell in a first direction. Since the first and second directions are orthogonal to the third and fourth directions, the networks can simultaneously utilise frequencies from similar bands, as discussed in more detail below.

A basic requirement of any transmission network is that a sufficient carrier-to-interference (C/I) ratio is maintained. The necessary C/I ratio varies, depending mainly upon the modulation scheme used. In the case of a digital modulation scheme such as, for example, Quadrature Phase Shift Keying (QPSK), a C/I ratio must exceed about 12 dB. In an urban setting and at the frequencies of interest, this ratio translates to a distance ratio of four for like to like transmissions. Different digital modulation schemes may require correspondingly different C/I ratios.

For an FM modulated network, half channel interleaving can be used to create additional members in a frequency set. However, channel interleaving alone does not provide a sufficiently high C/I ratio. For this reason, a distance ratio of greater than three must be maintained between transmission sittings. In an FM network, like to like signals would require a distance ratio of the order of 15 times. Given relatively flat urban terrain and a restriction on transmission heights of about 20 metres, buildings, terrain and foliage provide sufficient isolation due to blockage of the undesired signal. If this is not the case and a site does not have an alternative path available then micro-cell in-filling can be employed to provide a signal of suitable C/I ratio.

As discussed above, to overlay the broadcast and broadband networks, an offset approach is used which makes the transmission of the two networks orthogonal. The cell overlap "petal" patterns of the two networks are also orthogonal. As best shown in Figure 9, signals from a given site in the broadcast network which pass through adjacent or nearly adjacent sites in the broadband outbound network are either tangential to that

network, or the distance ratio exceeds that required for, in this case, QPSK modulation. In some cases, an alternative path exists to the other site servicing the broadband services with a given cell.

A similar examination of broadband outbound transmissions on the Broadcast service shows that an alternative path exists in the majority of circumstances where interference might otherwise exist (see Figure 10). Where no alternative path is available, perhaps due to terrain or urban structures, micro-cell in-fills may be used to provide a suitable signal.

A return signal for the broadband service can potentially originate from any point within a cell, requiring that the receive antenna at the corresponding transmission site be omnidirectional. This means that directionality cannot be relied upon to increase the C/I ratio in relation to other signals being broadcast through the network. A practical solution to this problem has been to allocate an exclusive spectrum for the return path. The design of the return path network is therefore independent of both the broadcast network and the broadband outbound network, and can only interfere with itself if it reuses its allocated frequencies in the reserved spectrum. In any case, frequencies used for return paths can not simultaneously be used to provide another return path to the same transmission site. This being the case the network as outlined in Figure 11(a) & 11(b) is presented. Given the symmetry of the network it can be derived that the return network within each cell services an area of:

$$A \quad = \quad d^2/4 \quad \text{(where d = the diameter of the cell)}$$

Given:

HH = 1,500

P = 50%

S = 2 (one telephone and one internet service)

d = 2 km

where:

HH = household density per square kilometre

P = penetration or uptake rate for services

S = average number of 64Kbit services provided

QPSK modulation yields 2 Mbit (E1) data channel per 2 MHz of spectrum

30 x 64Kbit services per E1 channel

then the bandwidth required for the broadband return path is: $B = 100$ MHz

Given a spectrum allocation of 1 GHz, the following allocation is possible:

A band: 850 MHz

B band: 100 MHz
Reserved for future use: 50MHz

Therefore a 42 channel FM NTSC or 25 channel FM PAL broadcast service could be supported. As the broadband service requires only 100 MHz then 650 MHz of the A band could be used for return links (polarisation is also possible) to form clusters of cells with the central node of the cluster interconnecting with a Broadband backbone (refer to Figure 6).

Other configurations are possible. Assuming the broadcast service is digital, or fewer analog channels are required, and each transmission point in the broadband service is interconnected to the Broadband backbone then it is plausible that the broadband data rate available per square kilometre may be derived from:

$$d^2 \quad = \quad 1.333 \text{ Mbit} \qquad \text{(for QPSK, where d is diameter of cell)}$$

Therefore for $d=2$ km, a 333 Mbit data rate is available.

The frequency sets in the preferred form of the invention are derived from the allocated spectrum on the following basis:

Broadcast Service:

A_V A band with Vertical Polarisation

A_H A band with Horizontal Polarisation

A_{VI} A band with Vertical Polarisation and Half Channel Interleave

A_{HI} A band with Horizontal Polarisation and Half Channel Interleave

Broadband Service Outbound Transmission:

A_{LV} Lower half of the A band with Vertical Polarisation

A_{LH} Lower half of the A Band with Horizontal Polarisation

A_{UV} Upper half of the A Band with Vertical Polarisation

A_{UH} Upper half of the A Band with Horizontal Polarisation

Broadband Service Return Path Transmission:

B_{LV} Lower portion of the B band with Vertical Polarisation

B_{MV} Middle portion of the B band with Vertical Polarisation

B_{UV} Upper portion of the B band with Vertical Polarisation

B_{LH} Lower portion of the B band with Horizontal Polarisation

B_{MH} Middle portion of the B band with Horizontal Polarisation

B_{UH} Upper portion of the B band with Horizontal Polarisation

This allocation is shown in Figure 5.

As shown in Figure 6, cells may also be clustered to form a node interconnection point, assuming the to/from relay links are also QPSK modulated. Of note is the offsetting of the clusters in order to ensure the concentrated links from/to the node do not align with an adjacent cluster as the distance ratio would not provide sufficient carrier to interference (C/I) isolation.

Turning to Figures 11(a) and 11(b), there is shown a return path arrangement for the broadband network. The segments use frequencies selected from the B spectrum shown in Figure 5, along with vertical and horizontal polarisation in accordance with Figure 11(a). In this way, the network arrangement shown in figure 11(a) makes relatively good use of the allocated spectrum. Typically, the receivers used for the return path of the broadband network use the same directional horns as the transmitters.

It will be appreciated that the present invention includes within its scope all suitable digital and analog modulation schemes. Similarly, the actual frequencies at which the invention may be applied may vary depending upon terrain and other variables. Whilst these frequencies will typically lie in the range of 10 GHz to 50 GHz, the invention may be implemented with frequencies outside of this range, so long as the signals are sufficiently directional.

Although the invention has been described with reference to a number of particular embodiments, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.